**DEPARTMENT OF THE NAVY**
OFFICE OF COUNSEL
NAVAL UNDERSEA WARFARE CENTER DIVISION
1176 HOWELL STREET NEWPORT RI 02841-1708

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1176 HOWELL ST.
CODE 00T2, BLDG. 102T
NEWPORT, RI 02841

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| Inventor | Paul V. Cavallaro et al |

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Attorney Docket No. 300153

# ROBUST SOFT TEXTILE TRANSFER CASE FOR CONTAMINATED MATERIALS

**[0001]** The present application claims the benefit of United States Provisional Application Serial Number 62/382,313 filed on September 1, 2016 by the inventors, Paul Cavallaro, Andrew Hulton, Gregory Gudejko and Dustin Green and entitled "Robust Soft Textile Transfer Package for Contaminated Materials".

## STATEMENT OF GOVERNMENT INTEREST

**[0002]** The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

## CROSS REFERENCE TO OTHER PATENT APPLICATIONS

**[0003]** None.

## BACKGROUND OF THE INVENTION

### (1) Field of the Invention

**[0004]** The present invention applies to the field of containers used in the transport of biologically or chemically contaminated hazardous contents.

**(2) Description of the Prior Art**

**[0005]** Current international standards impose strict requirements on the air transport of biologically and chemically hazardous materials. Existing container solutions are designed for small samples rather than larger contents. The maximum stress and stress distributions in larger containers vary considerably based on the size, shape and wall thickness of the container. While safe shipping requirements are attainable for small scale containers at a given internal pressure; larger scale containers encounter significantly higher stresses at the same internal pressure due to the increased volume of the container.

**[0006]** Also, significantly greater stresses are developed during drop impact and puncture tests due to the increased content and container weights. Working and shipping standards for use require a leak-proof seal without an allowance for pressure relief. While the container would likely never need to be re-opened after the insertion of the contaminated contents; ease of use in portability (a low weight) and time to seal the container (sealing in less than 30 minutes) are desired.

**[0007]** As such, there is a need to increase transfer container sizes in order to accommodate the safe transport of contaminated human remains and other comparably sized contents. Performance metrics require that the containers be sealable within thirty minutes after the insertion of the contents; be puncture resistant; be leak-proof at a hydrostatic pressure of at least thirty-six pounds per square inch; remain leak-proof after a thirty foot drop when filled with water to at least a ninety-eight percent capacity by volume; be transportable by air and by an industry-sized pallet; prevent rapid decompression without a method for pressure relief; and not exceed two hundred pounds in weight. The requirements for a larger container should also permit the use of multiple material components and layers.

## SUMMARY OF THE INVENTION

**[0008]** Accordingly, it is a general purpose and primary object of the present invention to provide a high strength and comparatively high volume impermeable container.

**[0009]** It is a further object of the present invention to provide a low weight container that can be used for the safe transport of biological and chemically contaminated hazardous contents.

**[0010]** In order to attain the objects of the present invention, a robustly constructed container is provided. The container is a soft goods transfer case having a film-laminated, woven para-aramid synthetic fiber textile exterior layer. The exterior layer is a circular woven preform constructed without seams and of continuous warp yarns along a longitudinal axis and continuous weft yarns along a hoop (circumferential) axis. In a final form for use, the soft transfer case is shaped as a soft flexible lay-flat structure similar to a large woven fabric circular air beam.

**[0011]** To prevent air leakage during operation, the soft transfer case has a molded elastomeric bladder containable within the outer circular woven preform. The fabric layer of the woven preform resists expansion when the interior bladder is inflated. The woven preform resembles an open cylinder, and when assembled with the bladder and end clamps, prevents leakage of fluids and gasses. Such a circular woven preform eliminates lengthwise seams and requires only two mechanical terminations - one termination with end clamps at each end of the circular preform. Also, the structural and air-retention functions are not performed on the same layer with strength of the structure provided by the exterior fabric layer of the preform and air(gas)/fluid retention provided by the bladder enclosed in the preform. The strength of the transfer case and the air/fluid retention functions are intentionally decoupled.

**[0012]** In use, the soft transfer case opens to allow the insertion of significantly larger sized contents of biologically or chemically hazardous materials. After insertion, the transfer case is then sealed to protect the transport of the materials against drop impact, puncture and rapid decompression. After the insertion of the materials into the transfer case, the transfer case will likely never be reopened.

**[0013]** The transfer case of the present invention is puncture resistant and leak proof at a hydrostatic pressure of at least thirty-six pounds per square inch. The container remains leak-proof after a thirty foot drop at thirty-two degrees Fahrenheit and a greater than three foot drop on a rigid rod having a diameter of one and a half inches. The transfer case is also air transportable and resistant to rapid decompression. Furthermore, the transfer case enables the safe repatriation of biologically or chemically contaminated human remains, animal remains, protective equipment or other material in accordance with existing standards of use.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** Other objects, features and advantages of the present invention will be better understood by means of a detailed description of the drawings that illustrate the principals of the present invention in which:

**[0015]** **FIG. 1** depicts a dimensioned isometric view of a soft transfer case of the present invention;

**[0016]** **FIG. 2** is a plan view of the soft transfer case of the present invention with longitudinal retention straps and a mechanical clamping assemblies shown;

**[0017]** **FIG. 3** is a plan view of a mechanical end clamp used to close the soft transfer case of the present invention;

**[0018]** **FIG. 4** is a side of the mechanical end clamp of the present invention;

**[0019]** **FIG. 5** is a detailed view of the weave pattern for the textile outer layer of the soft transfer case of the present invention;

**[0020]** **FIG. 6A** depicts human remains inserted in the bladder of the soft transfer case of the present invention;

**[0021]** **FIG. 6B** depicts the bladder of the present invention with human remains inserted and with the bladder closed by sealing;

**[0022]** **FIG. 6C** depicts the bladder of the present invention inserted in the textile outer layer of the present invention;

**[0023]** **FIG. 6D** depicts the textile outer layer of the present invention with the mechanical end clamps attached; and

**[0024]** **FIG. 6E** depicts interior pressure vectors on the textile outer layer of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

**[0025]** Referring now to the drawings, and more particularly to **FIG. 1**, a soft transfer case **10** with an outer layer **12** is shown. The twelve inch dimension in the figure represents the approximate length of a transition of the transfer case **10** from a cylinder to a tapered geometry at mechanical end clamps **20** when the transfer case is subject to an internal pressure. The ninety-eight inch dimension represents the approximate length of a cylindrical region of the transfer case **10** when the transfer case is subject to internal pressure. A preferred overall length of the transfer case **10** is one hundred and twenty-two inches with a circumference of at least eighty inches.

**[0026]** As shown in **FIG. 2**, the soft transfer case **10** includes longitudinal retention straps **11** with the transfer case secured by the bolted mechanical end clamps **20** (See **FIG. 3** and **FIG. 4** for additional detail on the end clamps). The longitudinal retention straps **11** are flat webbing, similar to the material of seat belts and can be made of polyester fibers or any other similar structural material. The outer layer **12** of the transfer case **10** is a continuously woven, circular textile (i.e., Para-aramid synthetic fiber or other high performance fibers) preform layer (See **FIG. 5** for additional detail on the fiber arrangement of the preform layer).

**[0027]** In operation, the outer layer **12** reacts against pressurization; confines volumetric expansion of an internal bladder; and prevents puncture and impact damage. The textile layer **12** is optionally film laminated or surface coated; however, such a film or coating is only used to protect the fibers from environmental effects and is not to act as the primary bladder for pressure retention purposes. Flexible elastomeric coatings such as urethanes are appropriate for use, provided that the films or coatings behave as flexible membranes. The use of elastomeric films or coatings can be optionally applied to the yarns before weaving or sprayed/brushed on after the soft transfer case **10** is constructed. Laminations are generally only applied to the fabric after weaving.

**[0028]** As shown in **FIG. 6A-6E,** a layer enclosed by the outer textile layer **12** is a separate internal membrane that serves as an oversized (at a size at least fifteen-twenty percent greater than the inflated preform size) impermeable bladder **14** that can provide air retention. The gas/fluid retention member is the oversized bladder **14,** specifically the internal membrane of the bladder. After the bladder **14** is installed inside the outer textile layer **14** and upon inflation of the bladder, the expansion of the internal membrane of the bladder is resisted by the outer textile layer.

**[0029]** As shown in **FIG. 3** and **FIG. 4**, end terminations for the outer textile layer **12** are each a mechanical clamp **20** constructed of three components. The components are a solid rod **22** fitted within a slotted sleeve formed by clamshell plates **24** and secured by retention bolts **26** or other mechanical fasteners. This type of end clamp has been used successfully for strap-reinforced, braided inflatable air beams designed for military shelters.

**[0030]** Each end of the circular woven preform of the soft transfer case **10** is wrapped over a separate solid rod **22.** The slotted sleeve of a clamshell plate **24** is inserted over each rod **22** to secure the preform. The mechanical clamps **20**, as shown, do not engage and secure the bladder **14**. However, the mechanical clamps **20** can be optionally designed to simultaneously secure the bladder **14** and the outer textile layer **12**.

**[0031]** Upon pressurization of the bladder **14**, the preform of the outer textile layer **12** develops a cylindrical form (remote from the ends), as shown by the twelve inch measurements in **FIG. 1**, which then resists further expansion of the internal bladder. The stresses due to inflation are distributed to minimize concentrations and to avoid failures at rip points. This is an important reason for the fabric design approach of the outer textile layer **12** in which maximum stresses occur at the cylindrical region and not at the transition or clamped regions.

**[0032]** A clamping force is generated between the outer textile layer **12** and the mechanical clamps **20**. The mechanical clamps **20** apply an increasing restraining force upon increasing internal pressure. As shown in **FIG. 4**, the mechanical end clamp **20** with an optional bonded elastomeric liner **28** assists in reducing stress concentrations in the outer textile layer **12** at an interface of the clamp.

**[0033]** As shown in **FIG. 5**, the preform of the outer textile layer **12** is formed by using plain-woven and dense fabric architecture. A circular weaving process produces a rightcircular cylinder of the outer layer **12** with open ends and no seams. Dense implies that the plain weave is tightly woven so that light cannot shine through and that pointed objects will not force the yarns to separate (migrate) away from the point of impact or puncture. Denseness of the textile preform is controlled by the number of warp and weft yarns per unit distance of fabric.

**[0034]** In a plain woven fabric, the warp yarns cross over and under consecutive weft yarns. Warp yarns are oriented along the longitudinal axis of the formed cylinder of the outer textile layer **12** of the soft transfer case **10.** Weft yarns are aligned along the hoop or circumferential direction of the cylinder of the outer textile layer **12.** As known in the art, warp yarns are in a longitudinal direction and weft yarns are in a hoop or circumferential direction to form the continuous cylindrical structure of the outer layer **12.**

**[0035]** The highly dense, tightly woven fabric achieves a maximum puncture resistance and damage tolerance. A multi-layer warp and weft pattern could be used to provide additional protection against puncture and burst. Fabric density increases with increasing numbers of warp yarns per unit circumference and weft yarns per cylinder length. High density tightly woven fabrics restrict relative yarn motions from occurring such that the interstices (spaces between yarns) remain negligible when the outer textile layer **12** is mechanically stressed. If the relative yarn motions are significant; the interstices can become sufficiently large; thereby, exposing the internal bladder **14** to potential punctures and impact damage from sharp or pointed objects.

**[0036]** Having a six-thousands of an inch diameter for the yarn is preferred but other diameters are possible with testing. Also, the yarns can be coated to minimize damage from weaving and to provide environmental protection when the soft transfer case **10** is used in field operations. A high performance fiber material is recommended for the fabric. PARA-ARAMID SYNTHETIC FIBER is such a material but other materials exist within this category such as Dimensionally Stable Polyester and VECTRAN (a liquid crystal polymer).

**[0037]** The bladder **14** is molded by using an elastomeric material in a pouch-shaped form having a single open end and is made of elastomeric materials such as urethane, rubber and silicone. The diameter and length of the bladder **14** is approximately ten to thirty percent greater than the diameter and length of the outer textile layer **12**. This is important because oversizing the bladder **14** prevents the bladder from being subjected to stress when the soft transfer case **10** is pressurized.

**[0038]** Silicone is one of many choices but urethanes are also candidates for use. The selected material of the bladder **14** will be, in general, based upon compatibility with gasses and fluids that are contained in the soft transfer case **10**. The elastomeric material must meet the biological and chemical resistance requirements. Silicone and other materials options exist, including thermoplastic urethane.

**[0039]** After molding, the open end of the bladder **14** is rolled up on itself to allow easy insertion of the contaminated materials inside the container. The bladder **14** requires only one seam which is used to permanently seal the open end. Seaming can be done at the point of use by a variety of known methods including heat sealing, adhesive bonding and RF welding.

**[0040]** More specifically, the sequence of operation is illustrated in **FIGS. 6A-6E** in which the bladder **14** is received for field use in a rolled up configuration. As shown in **FIG. 6A**, the contaminated contents (or human remains) are placed inside the bladder **14** as the bladder is unrolled or after the bladder is unrolled – depending on whatever is easier for the operator or the size of the remains. As shown in **FIG. 6B**, the bladder **14** is then sealed along the single open end seam and remains unstressed at an ambient pressure (i.e., $p_{internal} = p_{external}$). As shown in **FIG. 6C**, the bladder **14** with contents is inserted within the outer textile layer **12** and in **FIG. 6D**, the mechanical clamps **20** are attached with a seam of the outer textile layer folding over the bladder. The strength of the mechanical end clamps **20** is greater than the strength of the outer textile layer **12** to ensure that the outer layer will fail first.

**[0041]** During air transport, rapid decompression of a closed container can be a dangerous event and must not occur. When using the soft transfer case **10** at high altitudes; a pressure differential can develop such that the bladder **14** becomes internally pressurized as $p_{internal}$ is greater than $p_{altitude}$. The bladder **14** expands with the preform of the outer textile layer **12** but does so without stretching. The outer textile layer **12** then becomes biaxially stressed along the longitudinal and circumferential directions of the fabric; resists further expansion of the bladder **14**; and develops a shape that achieves static equilibrium. Static equilibrium is achieved when inflation causes the soft transfer case **10** to develop biaxial stress states so that a stationary or stable configuration (geometry) does not experience any dynamical effects (flutter, vibration, etc) is produced. Because the bladder **14** remains unstretched at all times in the presence of the remaining preform; no stresses are developed within the bladder.

**[0042]** The preform of the outer textile layer **12** resists the bladder **14** from freely expanding. If the bladder **14** is oversized for the volume contained by the outer textile layer **12** then the bladder cannot be subject to stress. The bladder **14** is restricted from straightening out to a full shape by the outer textile or fabric layer **12.** If the bladder **14** cannot completely straighten out; then the bladder cannot stretch and therefore the bladder cannot experience strain or stress.

**[0043]** Upon pressurization of the bladder **14**, the preform of the outer textile layer **12** expands and a mechanical restraining force is generated between the textile layer and the mechanical clamps **20.** When the bladder **14** is designed not to be secured to the mechanical clamps **20**; the bladder simply conforms to the presence of the rod **22.**

**[0044]** Several advantages using the chemically/biologically resistant soft transfer case **10** of the present invention include: the decoupling of the structural and air retention functions by utilizing physically and distinct separate layers; the use of an oversized elastomeric bladder **14** that, when inserted inside the smaller textile outer layer **12**, expands without stretching and therefore does not experience stress with internal pressurization such that air retention performance of the bladder and single seam remain independent of internal pressure; the use of soft good components such as the structural and bladder elements that enable roll-form delivery to point-of-use.

**[0045]** The outer layer **12** is used as a compliant structural layer that minimizes system weight and that minimizes stress from pressurization (the peak stresses are remote from the ends with stress distributions uniformly distributed remote from the ends).

The stresses from drop impacts are less than those produced in conventional rigid structures.

**[0046]** Also, the soft transfer case **10** of the present invention utilizes a woven fabric having orthogonally arranged fiber placement such that the fabric resists lengthwise expansion directly by the longitudinal fibers and therefore does not require the use of tension strap reinforcements although the longitudinal straps **11** are preferably used.

**[0047]** The structural benefits of using a circular woven material for the outer textile layer **12** is that upon pressurization, a cylindrical shape is developed and bi-axial stresses are uniformly distributed and remote from the ends. Furthermore, the maximum tensile stress is located in the cylindrical portion of the shape away from the clamped ends and localized stress concentrations and a 2:1 ratio of circumferential to longitudinal stress per unit distance is produced.

**[0048]** Another major advantage of the soft transfer case **10** of the present invention is that the outer layer **12** can be supplied to the field in roll form. Rolling the fabric outer layer **12** will minimize logistics, inventory and supply control activities. The proper length of the preform outer textile layer **12** can be unrolled and cut to the required length for further use.

**[0049]** It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

**[0013]** The foregoing description of the preferred embodiments of the invention has been presented for purposes of illustration and description only. It is not intended to be exhaustive nor to limit the invention to the precise form disclosed; and obviously many modifications and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

**ROBUST SOFT TEXTILE TRANSFER CASE**

**FOR CONTAMINATED MATERIALS**

## ABSTRACT OF THE DISCLOSURE

**[0050]** A soft transfer case for biological and chemical material is provided. The transfer case includes a film-laminated, woven textile exterior layer as a pouch resembling an open cylinder. The cylinder is capable of being clamped at each end of the cylinder. A pouch shaped and single open end elastomeric bladder capable of containing biological and chemical material can be contained by the exterior layer. The bladder requires only one seam which is used to permanently seal the open end with the material contained therein. Upon pressurization of the bladder, the exterior layer expands and a restraining force is generated between the textile layer and the clamps.

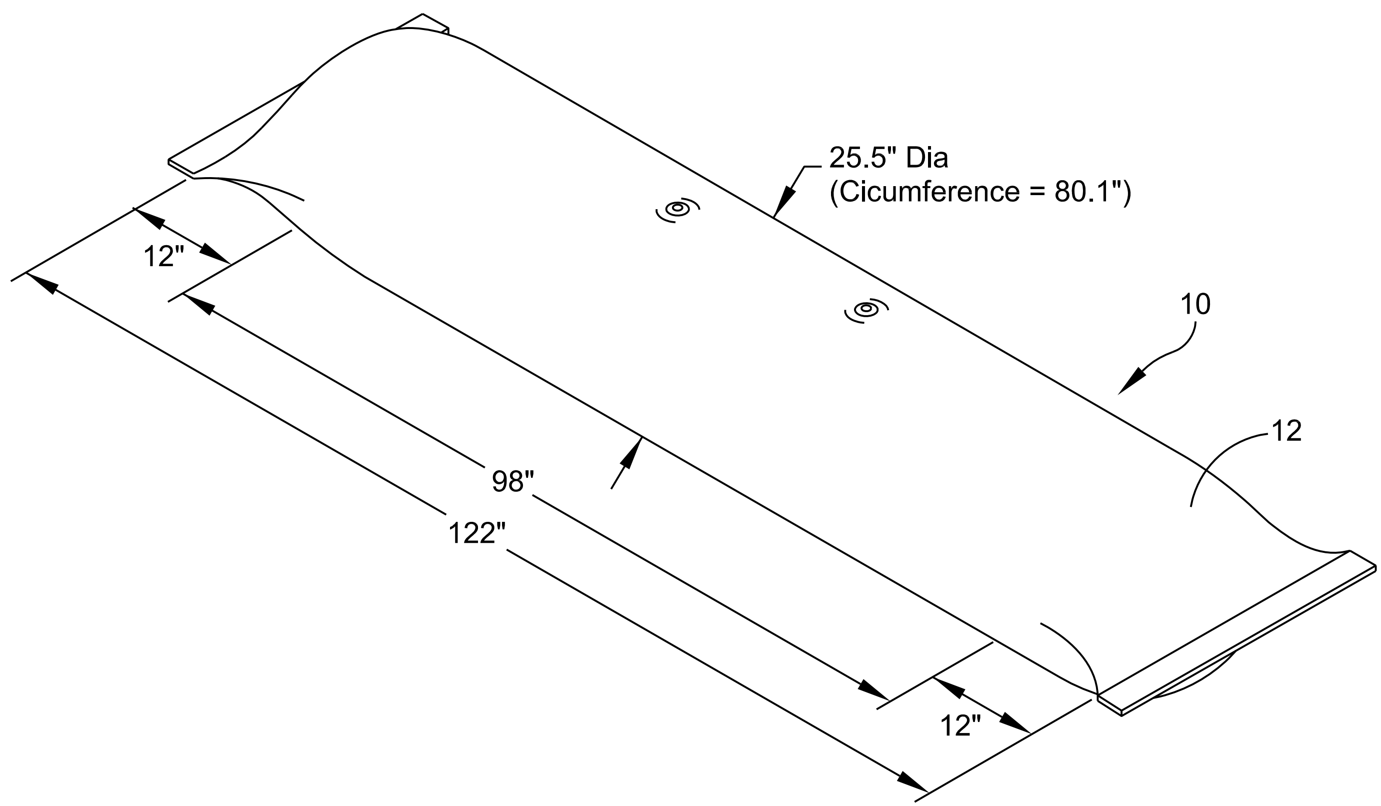



FIG. 1

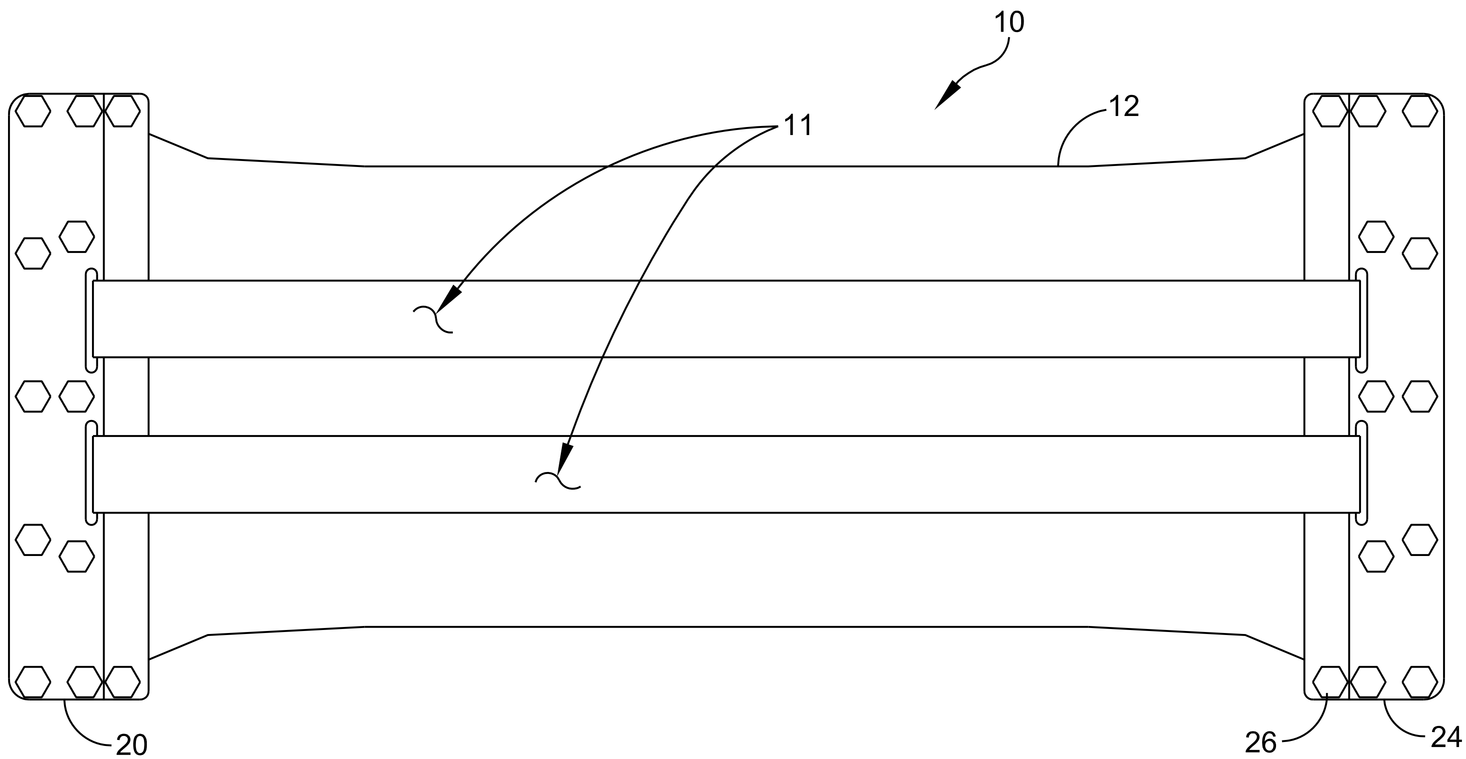
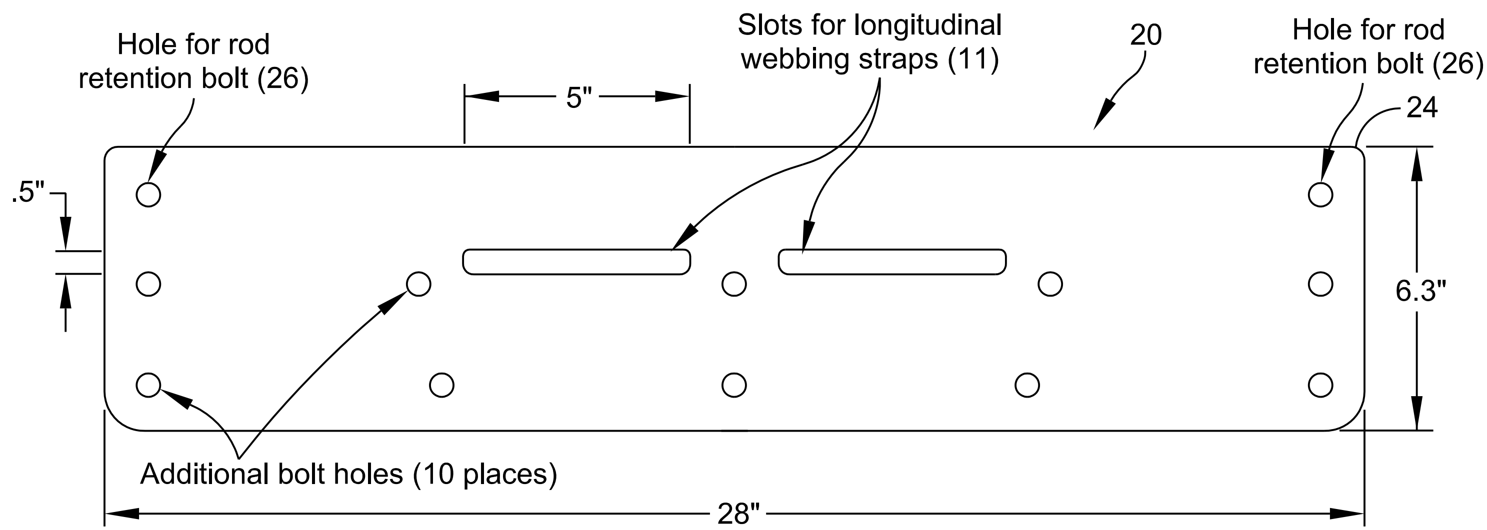



FIG. 2



Hole for rod
retention bolt (26)
5"
Slots for longitudinal
webbing straps (11)
20
Hole for rod
retention bolt (26)
24
.5"
6.3"
Additional bolt holes (10 places)
28"

FIG. 3

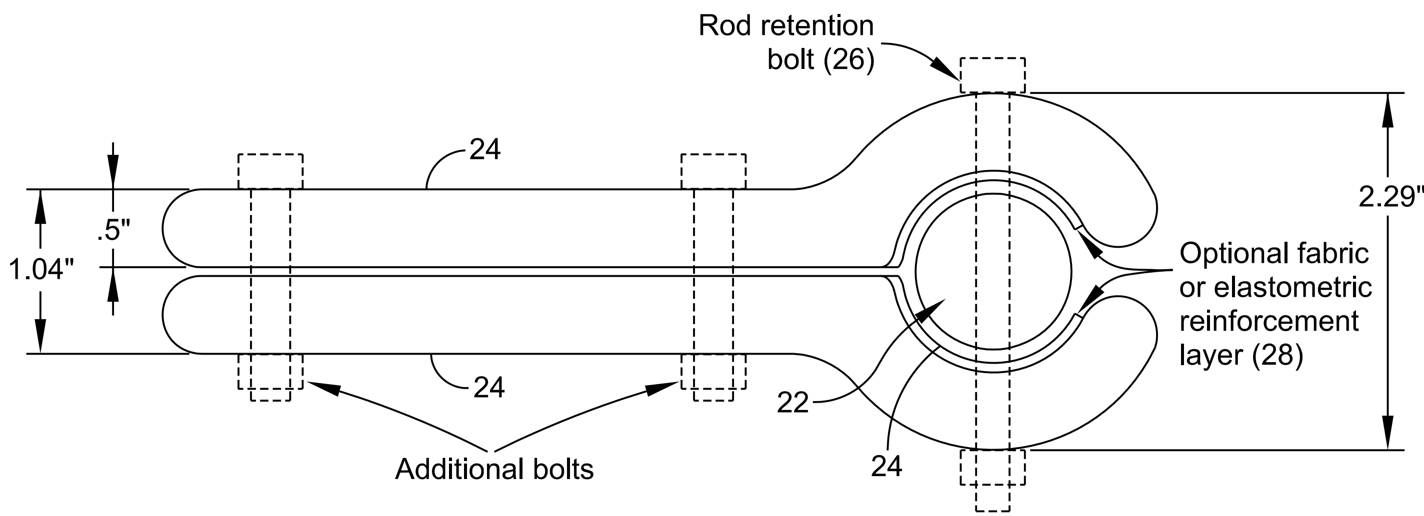
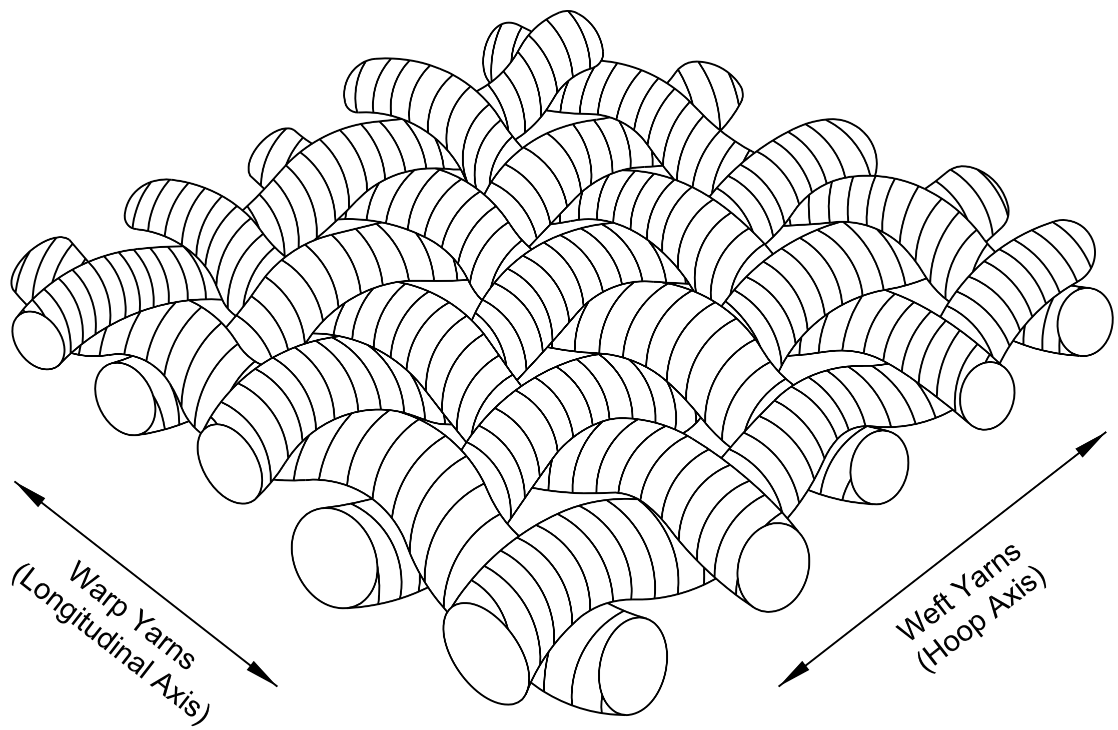

Rod retention
bolt (26)
24
2.29"
.5"
1.04"
Optional fabric
or elastometric
reinforcement
layer (28)
24
22
24
Additional bolts

FIG. 4




Plain Woven Fabric

FIG. 5

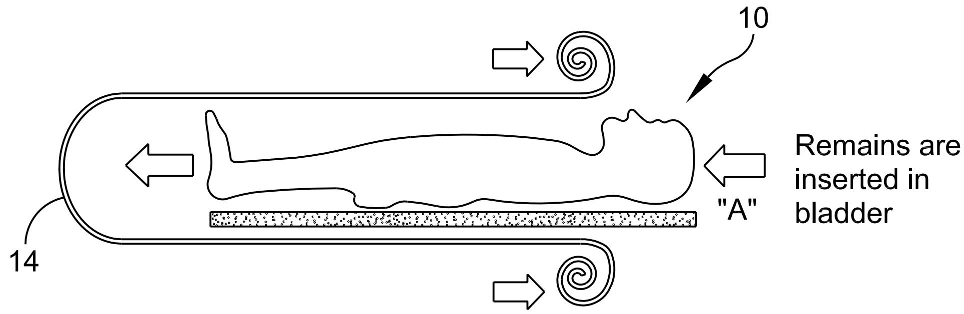



FIG. 6A

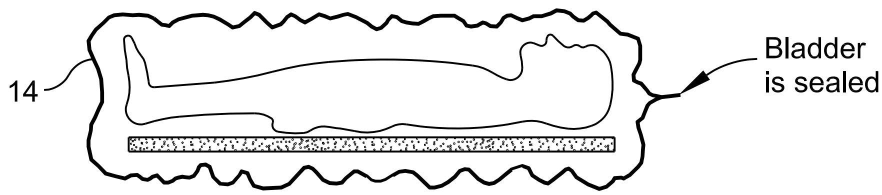



FIG. 6B

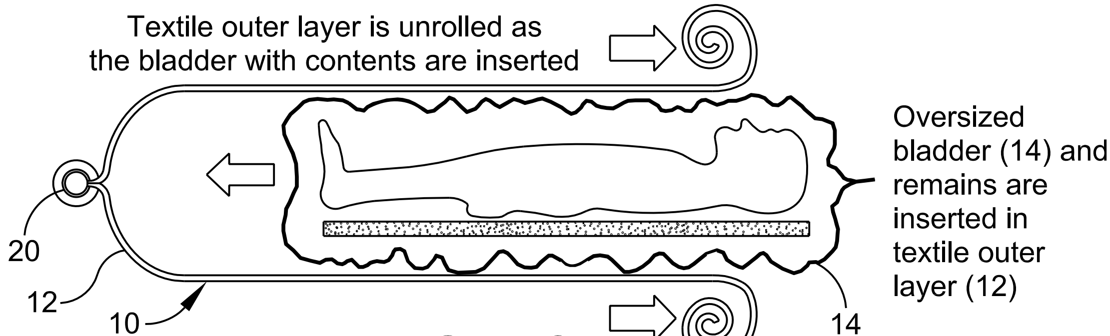



FIG. 6C

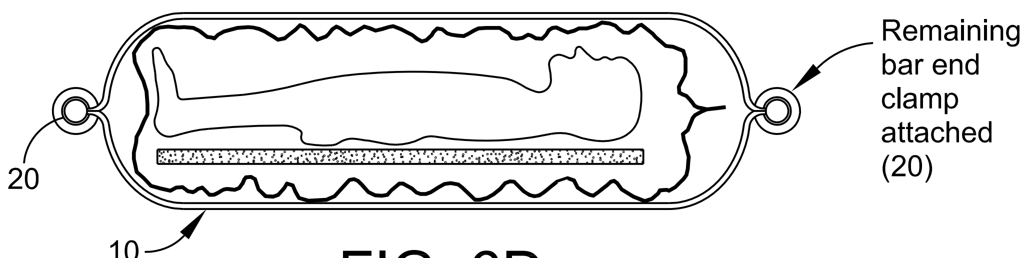



FIG. 6D

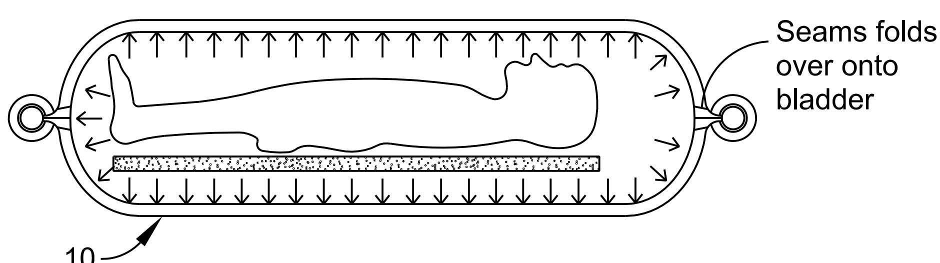



FIG. 6E